TRILATERAL EUREGIO CLUSTER

JÜLICH FORSCHUNGSZENTRUM

Status of technological development for the JULE-PSI project

A. Kreter, B. Unterberg, S. Kraus, M. Reinhart, L. Scheibl, B. Schweer and A. Terra

Institute for Energy and Climate Research - Plasma Physics, Forschungszentrum Jülich, Association EURATOM-FZJ, Trilateral Euregio Cluster, Germany

4th International Workshop on Plasma Material Interaction Facilities for Fusion Research (PMIF)

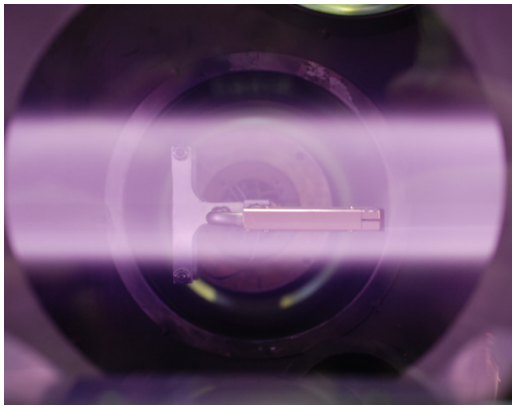
Oak Ridge / TN, USA, 9 September 2013

New research programme at FZJ in nuclear environment

- **An integrated concept to test neutron irradiated and toxic plasma-facing materials under high heat loads and plasma exposure in Jülich**
  - **Thermo-mechanical properties of plasma-facing materials (fatigue, shock resistance)**
    → Talk by J. Linke
  - **PMI processes defining availability of reactor (material erosion, fuel retention and dust formation)**

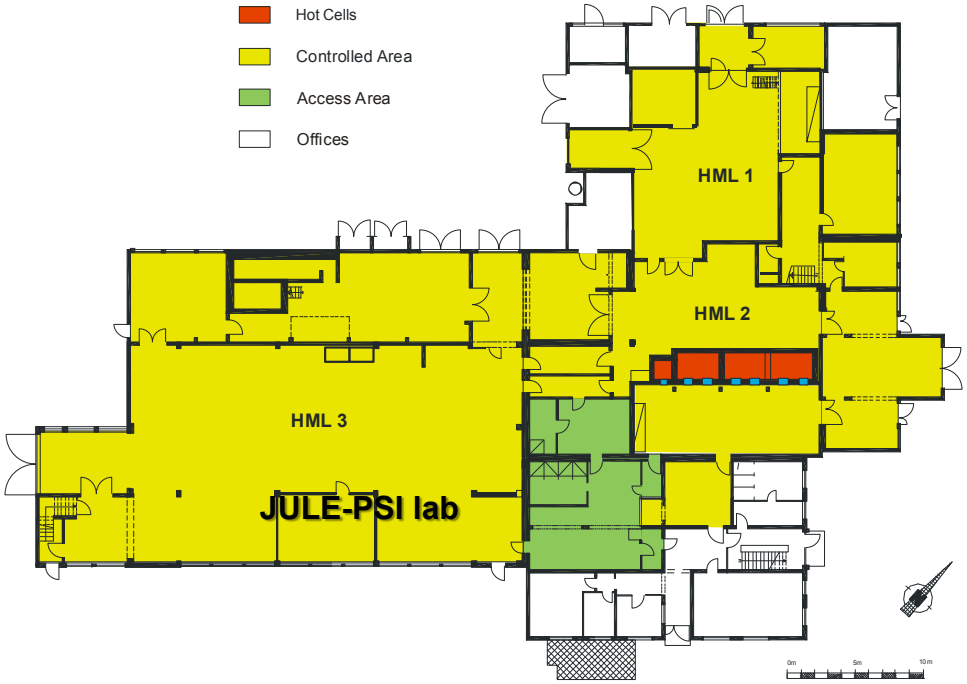
e-beam for high heat loads

Linear plasma for PMI processes



Refurbished Hot Material Lab (HML) in FZJ

Floor plan of HML building



Refurbished HML building

HML-3 for JULE-PSI

- **HML-1: JUDITH 2**
- **HML-2: JUDITH 1 Upgrade**
- **HML-3: JULE-PSI and Be analysis station**

JULE-PSI: Jülich Linear Experiment for PSI studies in Hot Cell

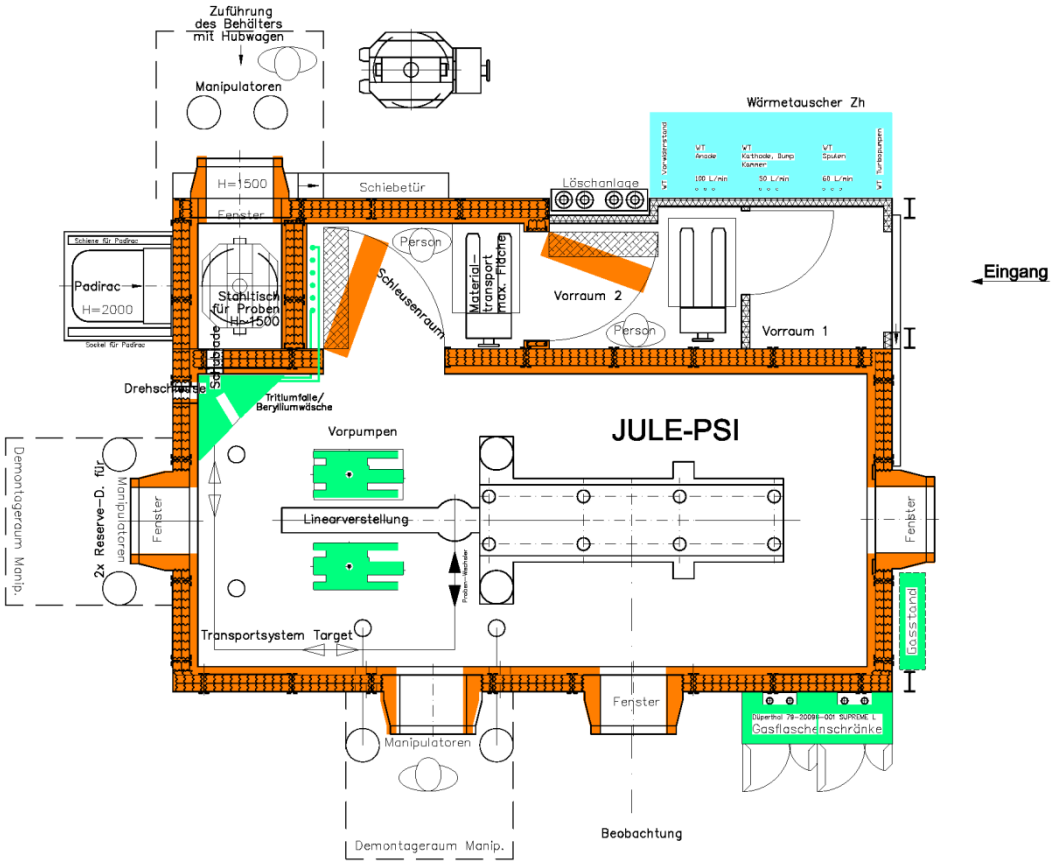
Based on PSI-2 / PISCES type device

Installation in the Hot Cell for handling of *radioactive* and *toxic* materials

PMI studies with

- **Neutron irradiated materials**
- **All wall materials incl. beryllium**
- **Low quantities of tritium**

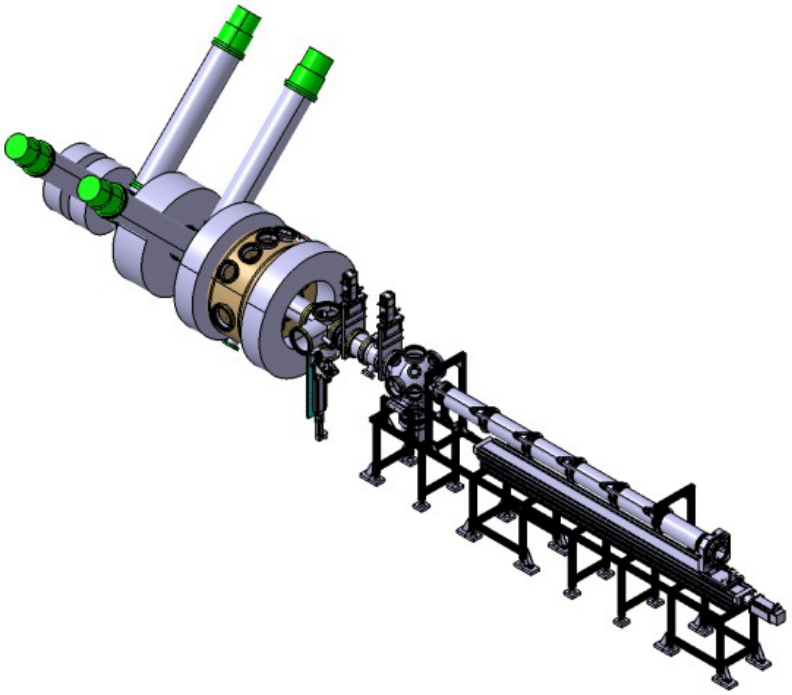
Envisaged JULE-PSI installation in hot cell

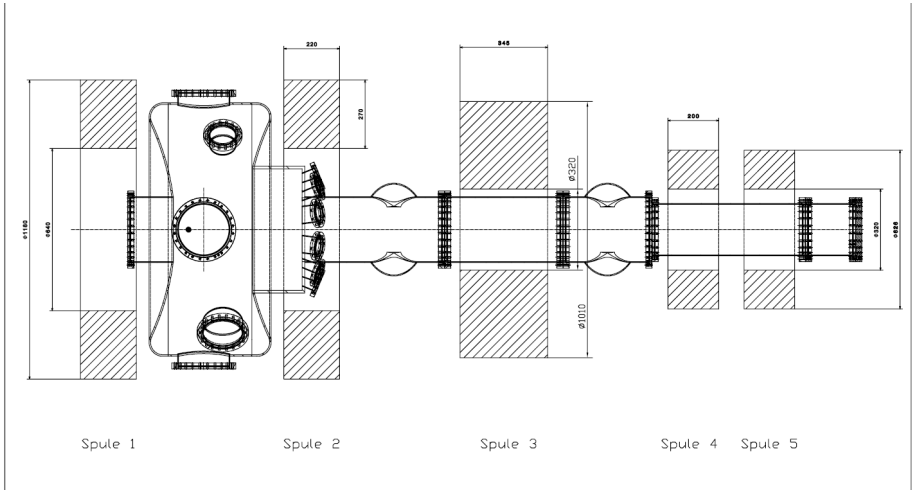


- **Refurbishing of Hot Material Lab is completed**
- **Conceptual design of Hot Cell is completed**
- **Material for hot cell (led bricks) is obtained**
- **Design review of hot cell installation is ongoing**
- **Licensing procedure for hot cell installation in 2014**
- **Installation of hot cell in 2015**

Conceptual design of JULE-PSI linear plasma device

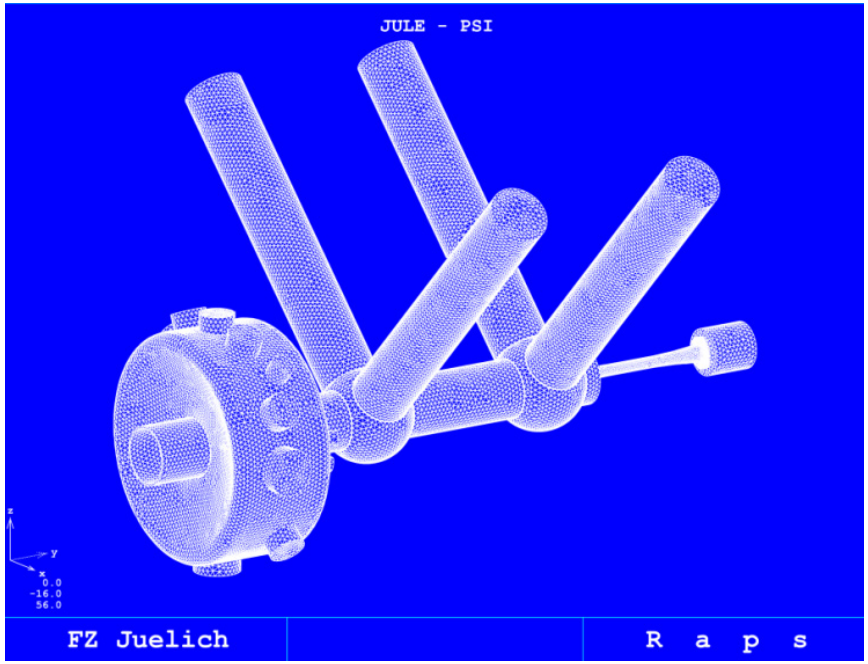
- **Steady state linear plasma generator (B = 0.2 T) with target exchange and analysis chamber, inside Hot Cell**
- **Loading conditions (deuterium plasmas), with target biasing**
  - $\Delta_{\text{flow channel}} \sim 6$ cm
  - $n_e = 10^{17} - 10^{19}$ m^{-3}
  - T_e up to 20 eV
  - $E_{ion} = 10\text{-}200$ eV (biasing)
  - $\Gamma_{ion} = 10^{21} - 10^{23}$ m^{-2}s^{-1}
  - Fluence: 10^{27} m^{-2} in 4 h
  - q = 0.1 - 2 MW m^{-2}, simulation of transients by laser irradiation (40 J / 1ms)
- **Installation in cold environment by the end of 2014**



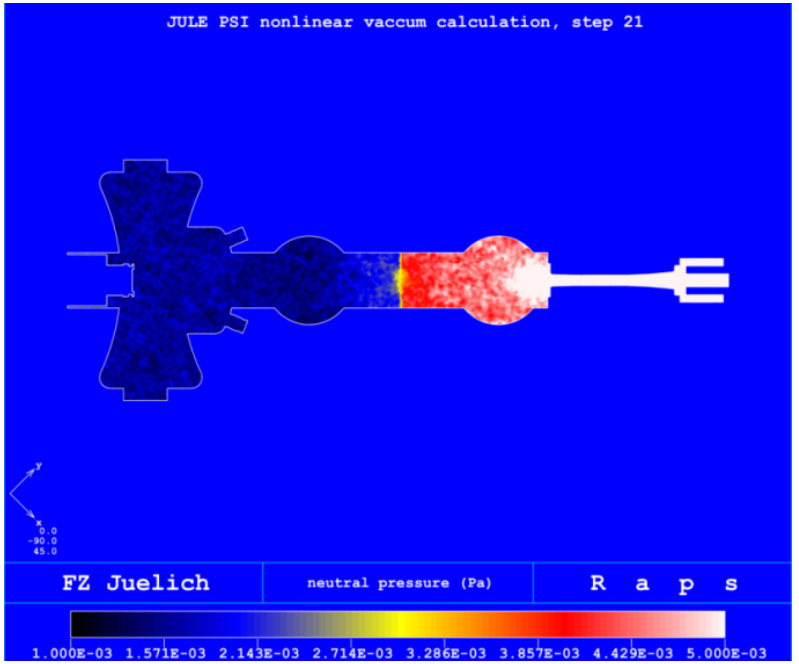


JULE-PSI: differential pumping system

Calculation grid of neutral gas transport code EIRENE



EIRENE simulations for gas puffing in plasma source

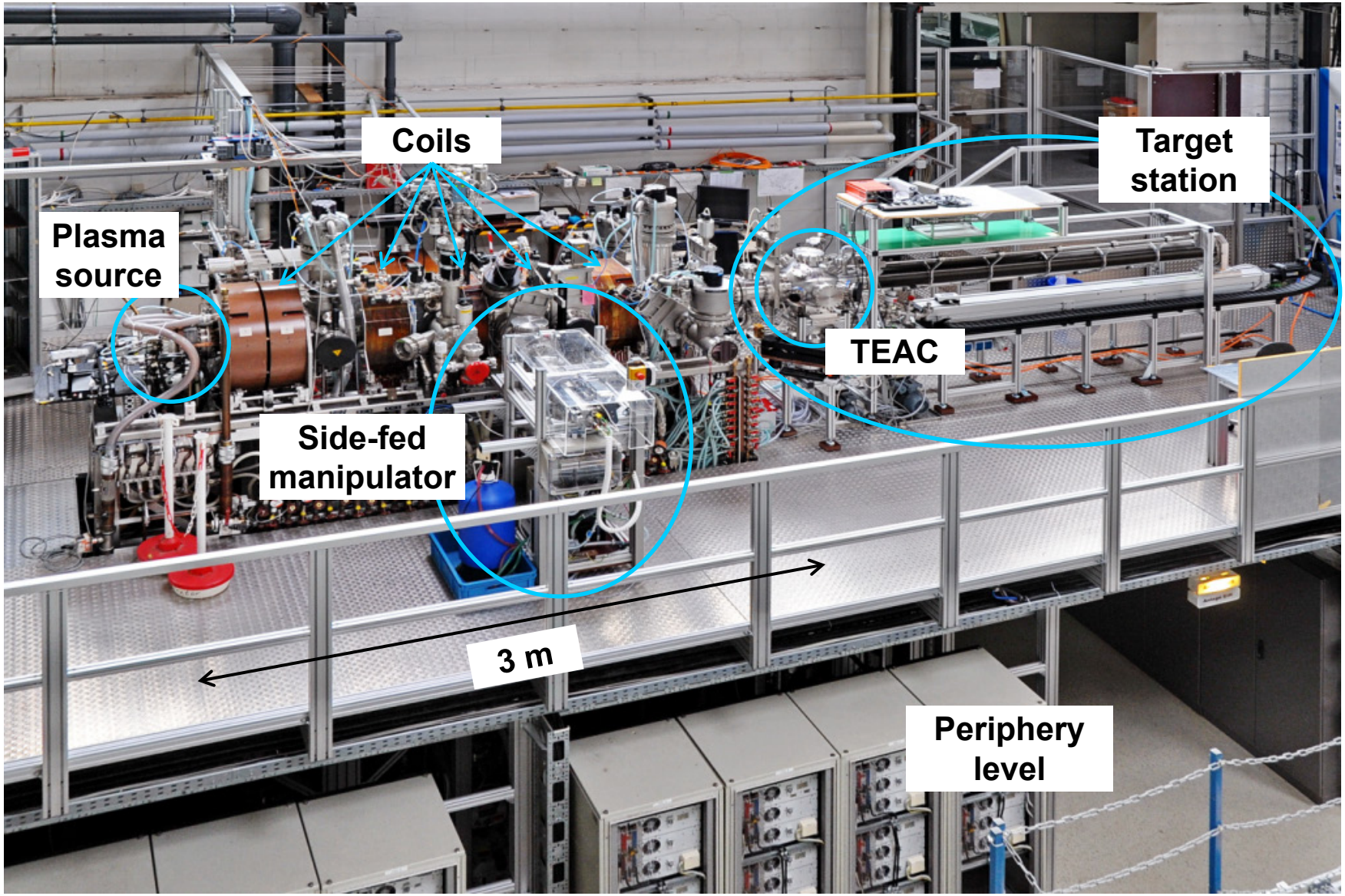


PSI-2 as the pilot experiment of the JULE-PSI project

- **PSI-2 linear plasma device was formerly installed at Humboldt University, Berlin and operated by IPP-Garching**
- **Transferred to FZJ in 2009 with following aims**
  - **Test-bed for components and solutions for JULE-PSI**
    - **Plasma source optimization**
    - **Sample manipulator and analysis station**
    - **Diagnostic development and optimization**
    - **Other peripheral components**
  - **Train personnel operating linear plasma device**
  - **Contribute to current PMI research topics**

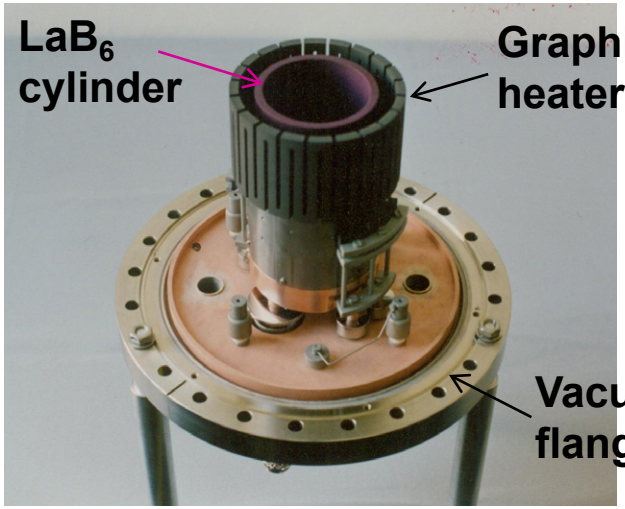
    → Talks by B. Unterberg and A. Huber

Installation of PSI-2 in Jülich

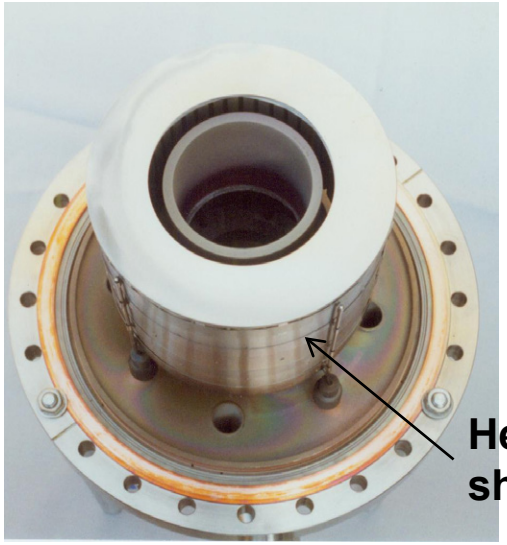


Plasma production by hollow cathode arc discharge

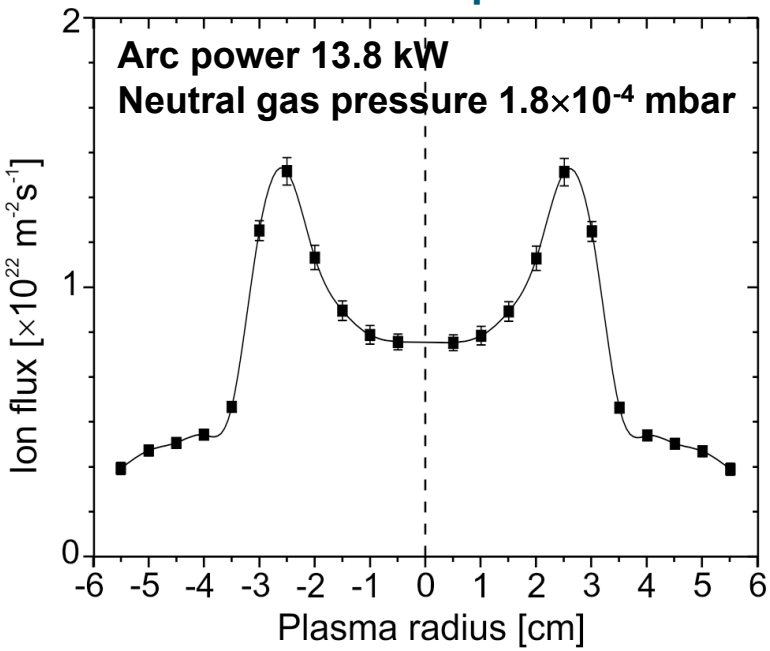
Cylindrical cathode unit with heat shield removed



Full cathode assembly

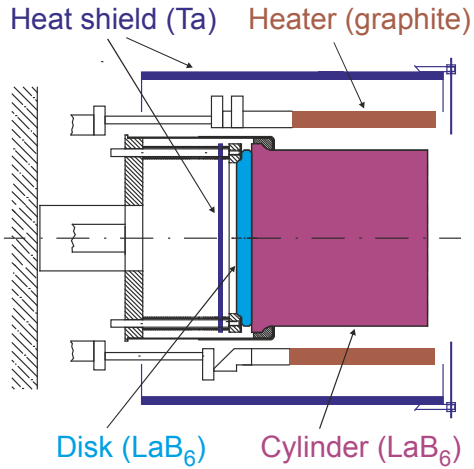


Langmuir probe measurements for deuterium plasma



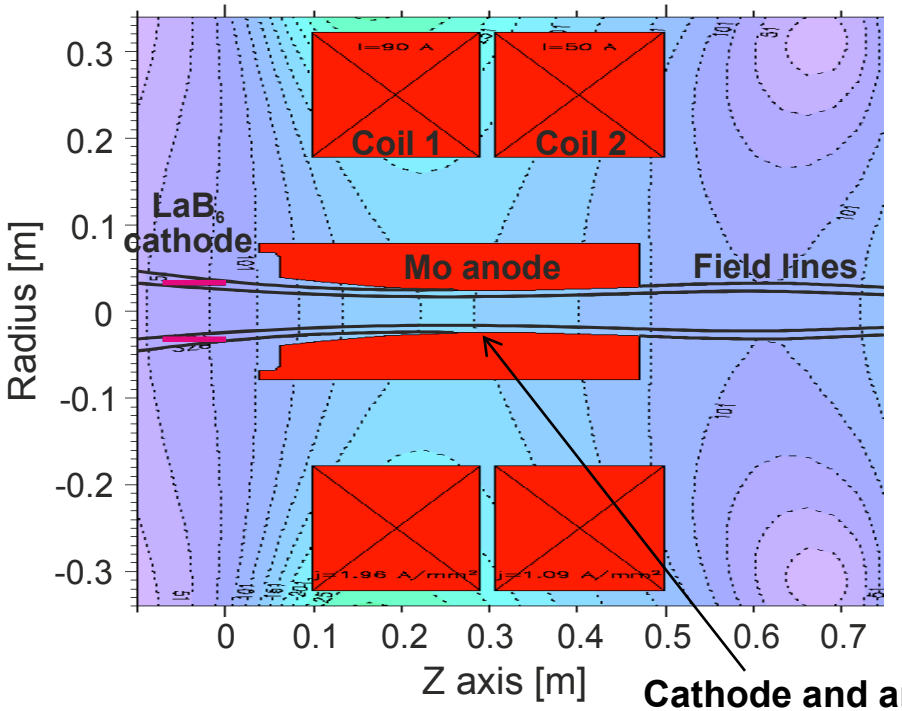
Hollow plasma profiles with the available source

'Closing' the back aperture by additional LaB_6 disk did not improve the shape of plasma profile



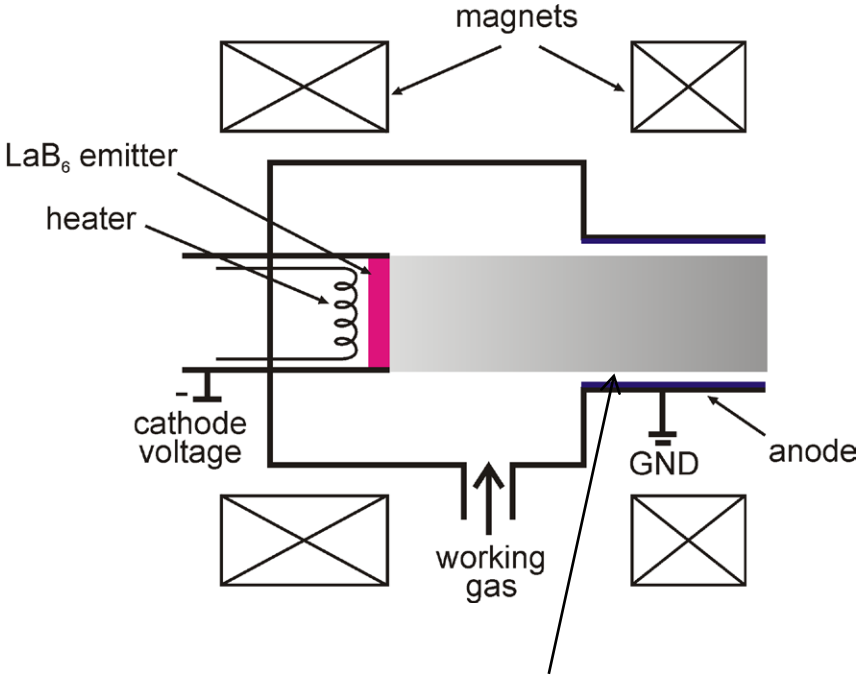
Approaches for plasma production using arc discharge with hot cathode

Geometry of PSI-2 ion source with cylindrical cathode



Cathode and anode connected by field lines

PISCES-type ion source with disk-shaped cathode



Discharge burns across B field

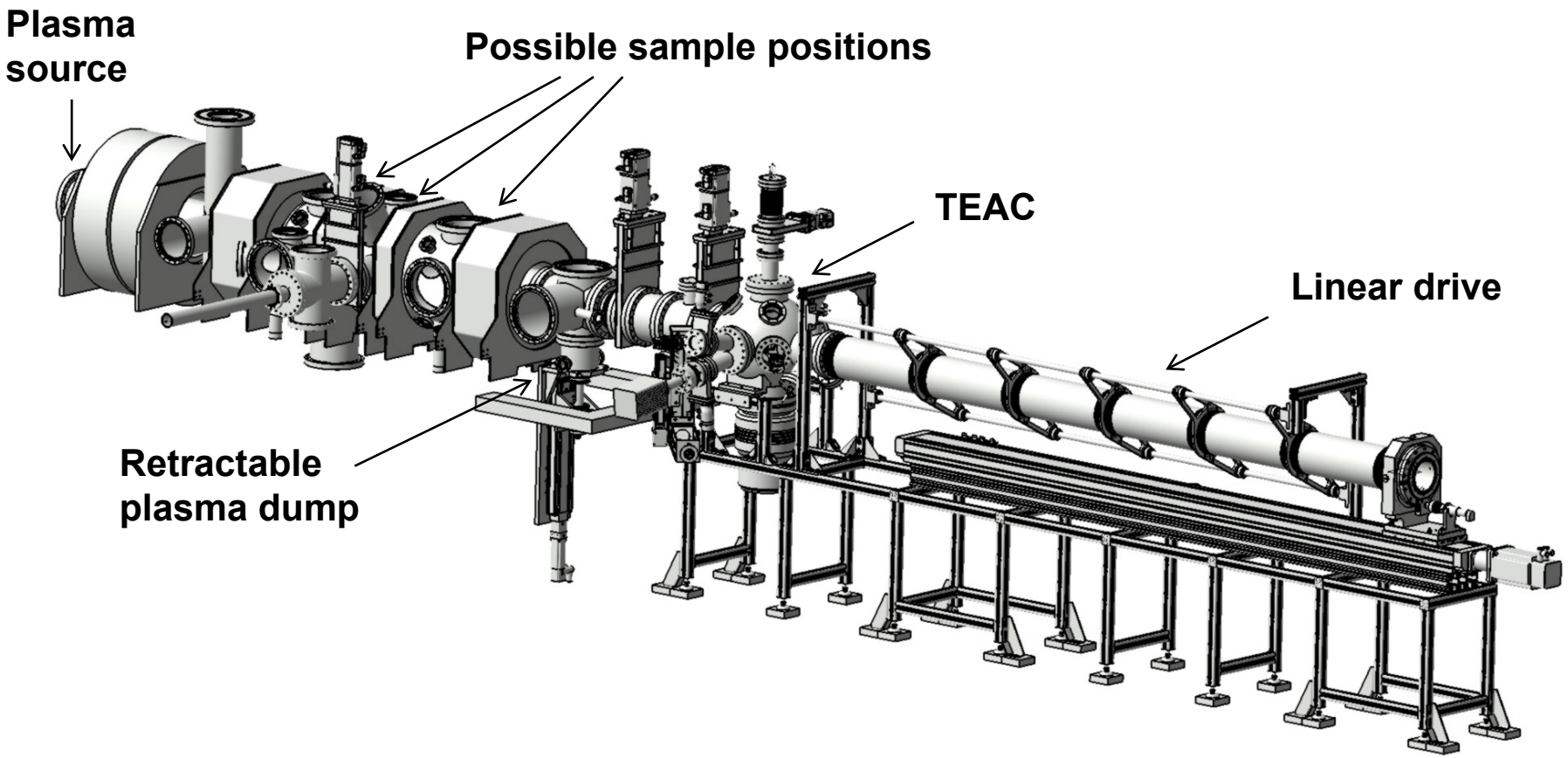
Two reasons for hollow plasma profile in PSI-2

- **Hollow LaB_6 cathode**
- **Connection between cathode and anode along field lines**

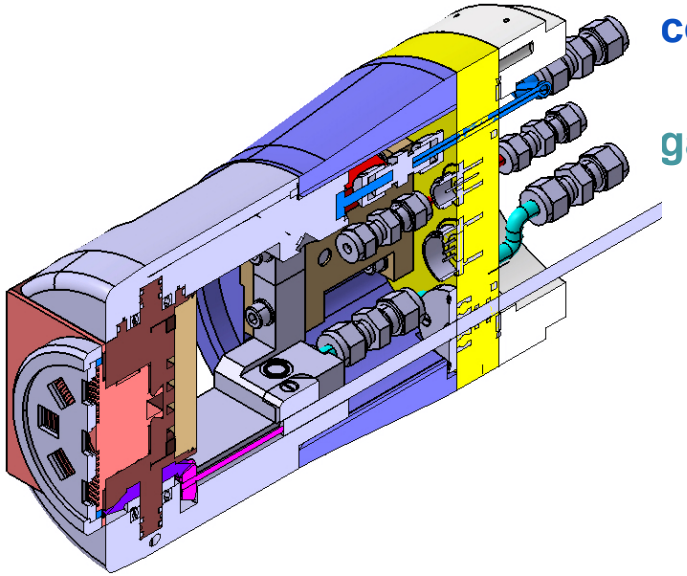
Strategy: adopting PISCES-like geometry of plasma source for PSI-2 and JULE-PSI, in collaboration with UCSD

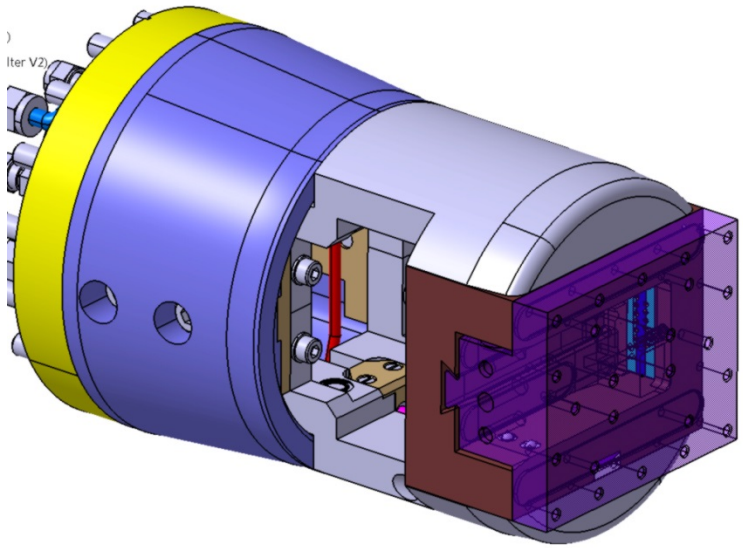
Installation of target station on PSI-2 completed

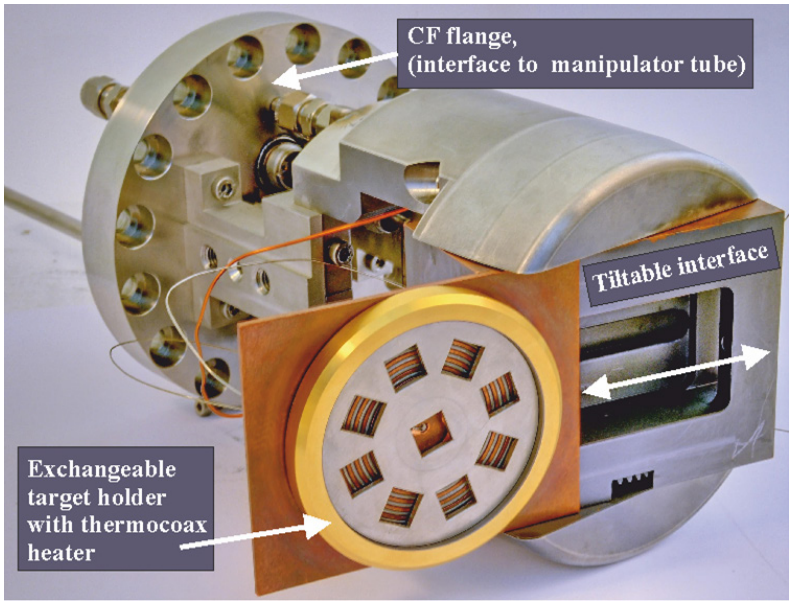
Target station includes back-fed sample manipulator and target exchange and analysis chamber (TEAC)



Target station: Head of sample holder

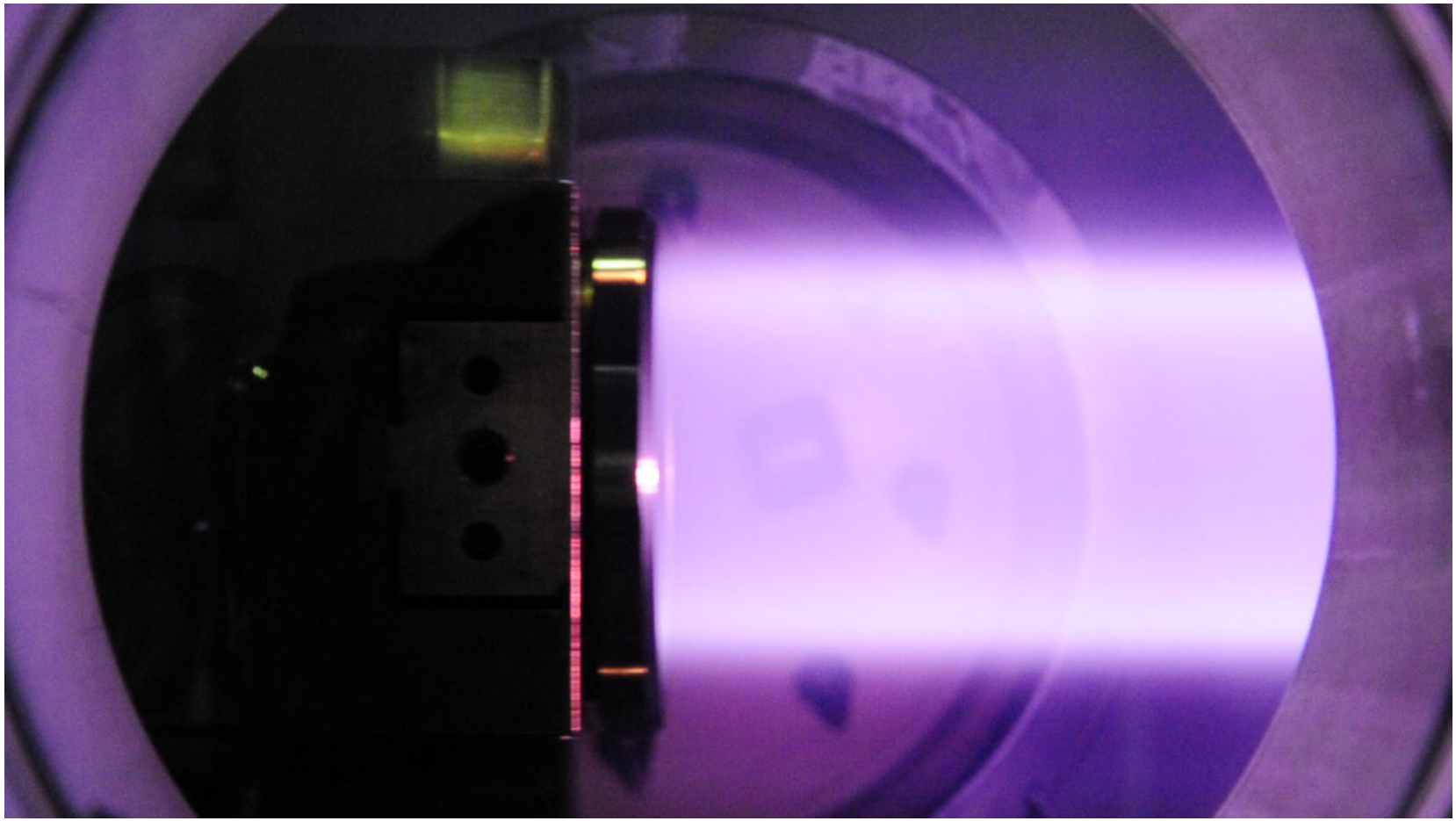






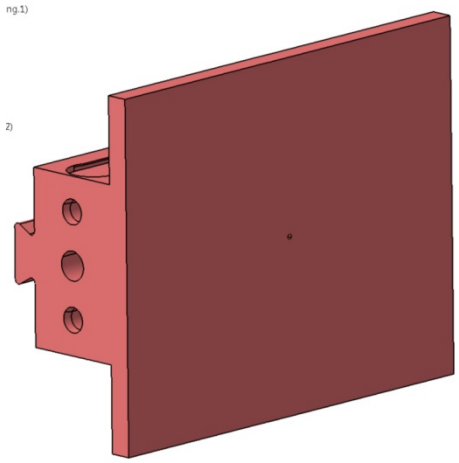
- Removable sample carrier with dovetail fixing
- Sample carrier fully rotatable and tiltable
- Electrical connections
- Sample temperature feedback-control by heating and cooling
- Gas feedthrough

Target station:
First exposure to plasma on 29/Nov/2012

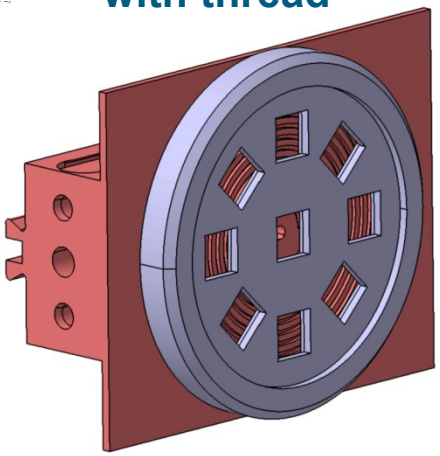


Target station: user-defined sample carrier

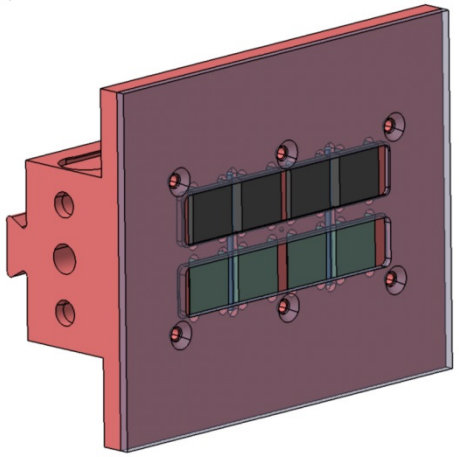
Generic sample carrier



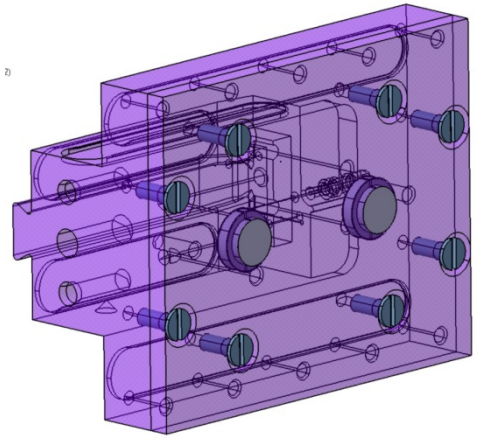
Heater and sample mask with thread



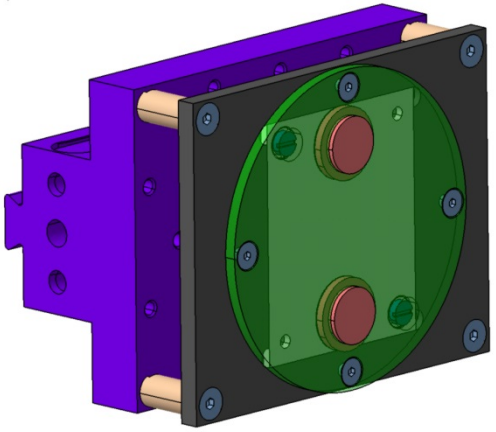
Sample mask bolted



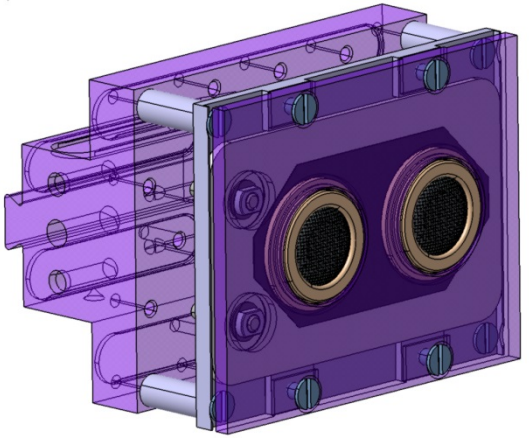
Sample carrier for low-temperature (RT-400°C) exposure



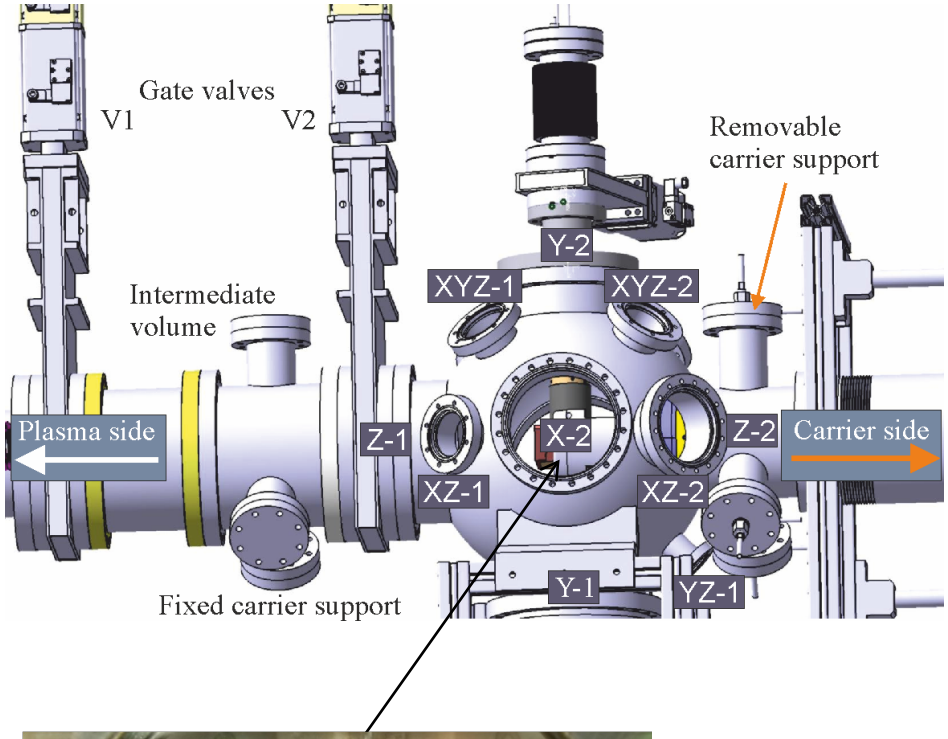
Sample carrier for high-temperature (400-1000°C) exposure

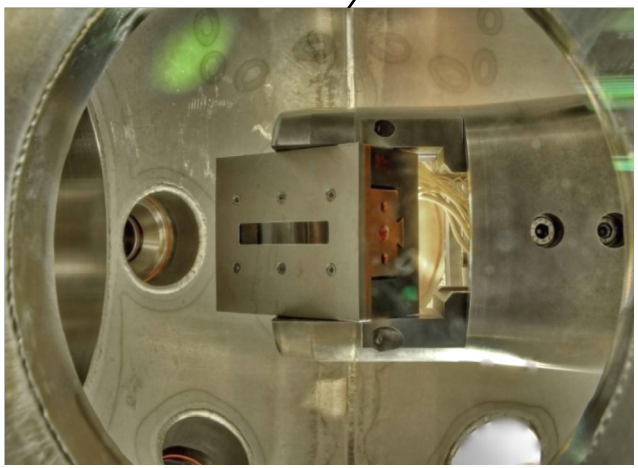


Sample carrier for liquid target exposure



Target Exchange and Analysis Chamber (TEAC)



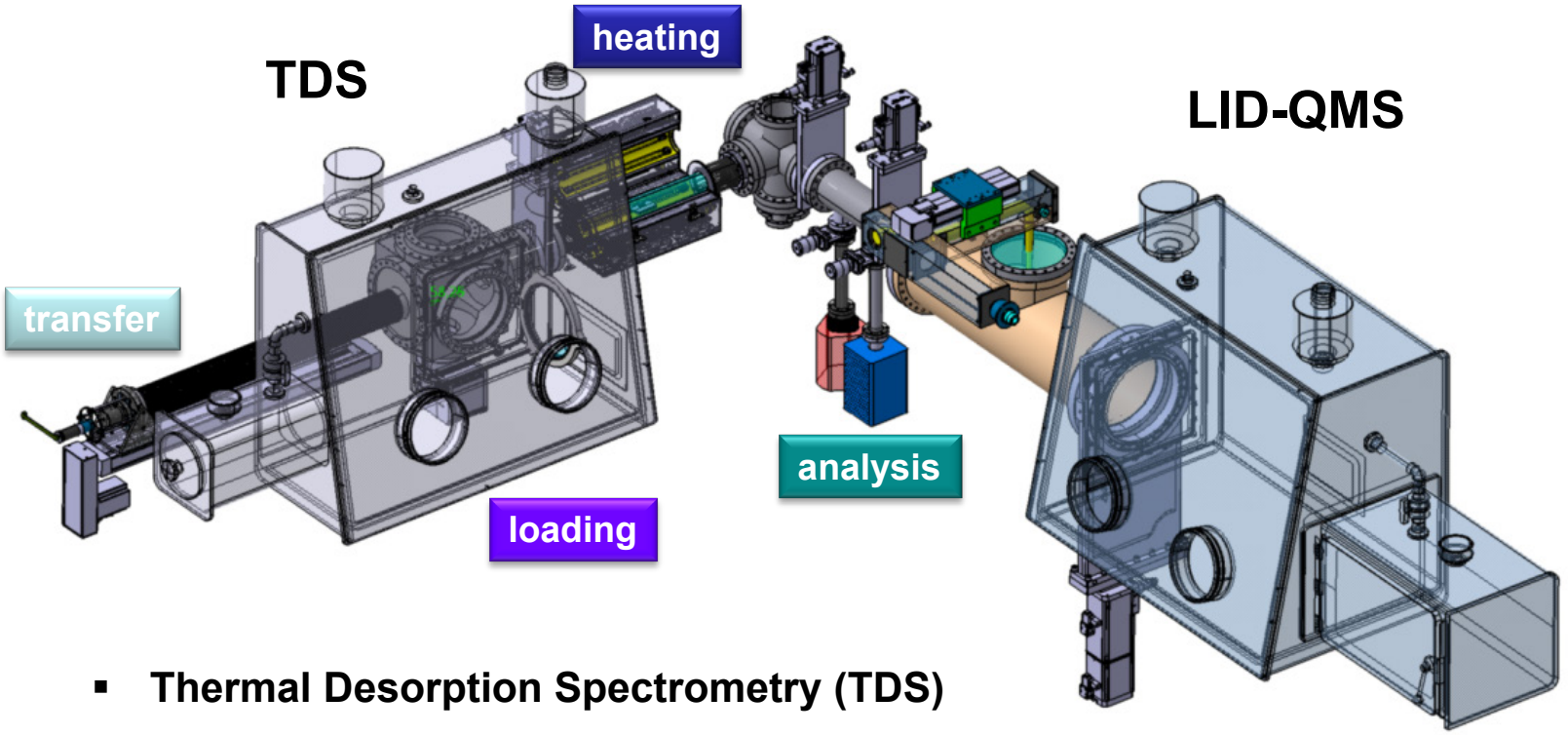


Allocation of vacuum ports

Type	Label	Description
CF200	Z-1	Transition target holder tube, plasma side
	V-1	Main pumping duct
	X-1	Loading port
CF150	Z-2	Transition for target holder carrier, manipulator side
	X-2	Diagnostic RGA
	Y-2	In-situ glow discharge spectrometer (GDOES)
CF-100	XZ-1	Diagnostic LIBS light observation
CF63	XZ-2	Diagnostic LIBS input
	XYZ-1	Target illumination
	XYZ-2	Far distance microscope
	XYZ-3	Not occupied
	XYZ-4	Not occupied
CF35	YZ-1	Vacuum gauges

Versatile beryllium analysis facility

Design and construction of a JET-oriented beryllium analysis facility (inside the controlled area of HML but outside the hot cell)



- Thermal Desorption Spectrometry (TDS)
- Laser-Induced Desorption of complete JET tiles using Nd:YAG laser
- Surface composition analysis by glow discharge spectroscopy

Expected to be operational in 2014

Summary

- JULE-PSI project foresees linear plasma device in nuclear environment for plasma-material interaction with neutron irradiated and toxic materials
- Refurbishing of Hot Material Lab is completed
- Installation of Hot Cell is being prepared
- Conceptual design of JULE-PSI device incl. vacuum vessel, pumping and magnet system is completed
- Design of versatile beryllium analysis facility is completed, main parts purchased, to be assembled in 2014
- PSI-2 serves as pilot experiment for JULE-PSI project
- Research on optimization of the arc source is ongoing;
  Helicon source is considered as possible alternative, collaboration with Budker Institute Novosibirsk
- Target station including target exchange and analysis chamber is operational
- Target station is used for ongoing PMI research

  → Talks by B. Unterberg and A. Huber